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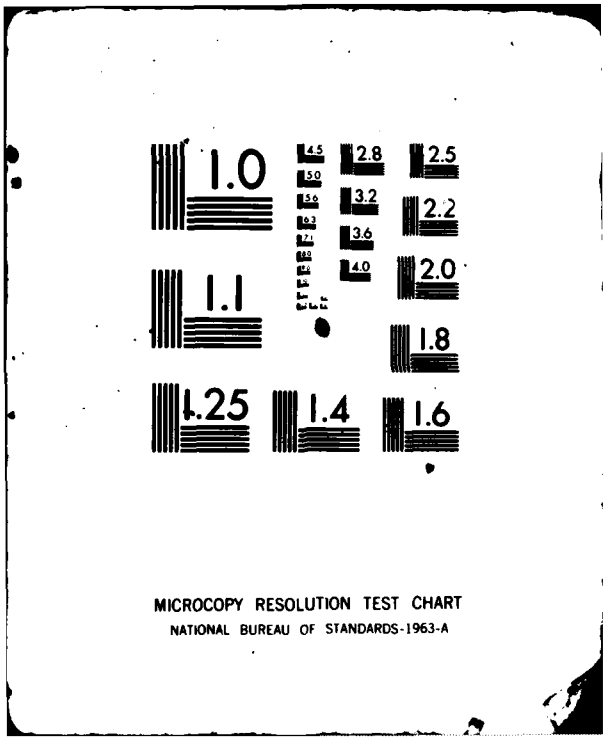
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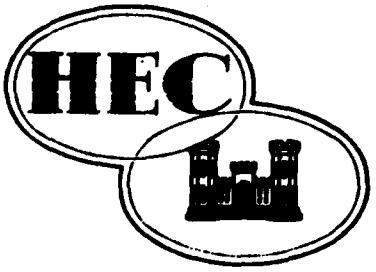
DATA MANAGEMENT SYSTEMS FOR WATER RESOURCES PLANNING

by

DARRYL W. DAVIS



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Water resources planning at the federal level is comprehensive multi-purpose multi-objective planning. The increasing complexity of issues, planning laternatives, and evaluation criteria have spawned an ever growing need for increased data and associated analysis procedures. The increased number of such models, both demanding and generating large amounts of data, have stimulated awareness of the need for planning oriented data management systems. This paper describes recent activities of the Corps of Engineers

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Data Management Systems for Water Resources Planning[1]

Darryl W. Davis, Member, ASCE[2]

ABSTRACT: Water resources planning at the federal level is comprehensive multipurpose multi-objective planning. The increasing complexity of issues, planning alternatives, and evaluation criteria have spawned an ever growing need for increased data and associated analysis procedures. The increased sophistication of computer simulation models, and the increased number of such models, both demanding and generating large amounts of data, have stimulated awareness of the need for planning oriented data management systems. This paper describes recent activities of the Corps of Engineers Hydrologic Engineering Center in data management for water resources planning studies.

DATA MANAGEMENT AND PLANNING

Planning Context and Data Management Role

Water resources planning in the Corps of Engineers is the product of decades of experience in performing both large and small studies and the collective sum of legislation, executive orders, court decrees, and interagency coordination. The Water Resources Council's Principles and Standards (1), and the Corps implementing guidance (2) govern both the substance and conduct of planning studies. The mandate is to perform studies in an open public decision making forum, consider the broad spectrum of resources management issues, and develop plans that provide balanced management of the nation's water resources. The phraseology associated with this charge is "comprehensive multipurpose, multi-objective planning". What this translates to at the level of the technologist is that a great variety of technical studies covering the spectrum from biological to social sciences, from demographic to engineering, from institutional to implementation are needed. Data must be assembled, analyzed, and interpreted; information must be extracted from the data, and the findings reported, documented and processed through several decision making bodies before the planning task is considered complete.

The role of data management as a concept is to facilitate this process in an efficient and effective manner. That is to facilitate defining the objectives, formulating and evaluating alternatives, and communicating findings in a simple yet complete manner. The number of specific studies and actions that involve a data management type operation for a typical planning study probably number in the tens to hundreds. The types of data management operations will range from simple hand

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[1]Presented at the August 1981 Water Forum '81 Specialty Conference, San Francisco, California.

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record keeping and transfers to interfaces with large, institutionally maintained data sets such as U. S. Census Bureau demographic files and streamflow records of the U. S. Geological Survey. From a practical and common sense standpoint it would seem inappropriate to attempt to create a universal data management system for all planning needs. It seems more appropriate to develop collected sets of data management concepts and systems that can then be selectively assembled to meet the specific needs of the study being performed.

Data Management Concepts

Data management concepts and systems that are relevant to water resources planning can be informally divided into several categories. Traditional information storage/retrieval systems that basically provide an "organized" repository of data comprises the first category. Typical of these are record keeping systems such as what might be used to maintain mailing lists and catalogue relevant regulations and legislation. A second category might be more technical data oriented such as might be used to catalogue data for subsequent statistical or selective tabular summary. Demographic data file systems would fit this category. The great majority of historical data management application in planning fall into this category . . in effect technical data storage/retrieval for simple analyses/display purposes. Another category might be those systems that by their inherent structure and use are either major contributors to or are powerful analysis tools in their own right. Systems of this type include certain spatial data management systems, and perhaps network/topologic systems. Spatial data systems will be discussed at length later. The last category that might be of interest are data management systems designed to facilitate the automated transfer of data to other uses, specifically as might be the case for exchange of data in a standardized manner between computer simulation models.

Each of these categories of data management systems is relevant to water resources planning and can contribute significantly to the efficient prosecution of the full range of activities needed to perform a planning study. The Hydrologic Engineering Center (HEC) has focused its attention on the subject of data management concepts that facilitate the analytical aspects of planning . . the formulation and evaluation of water resources management alternatives. As a consequence developmental work has been directed to the area of spatial data management (to facilitate comprehensive resource based analysis) and automated file creation/transfer (to facilitate the simple and efficient exchange of modelling data between computer simulation and analysis models).

Evolution of Data Management Systems at HEC

The HEC is a major creator and purveyor of computer software in the field of water resources management (3). In early years focus was primarily on programs that automated hydrologic engineering computations. In recent years, activities have broadened to include several other areas relevant to water resources planning including; general purpose water resources simulation models, flood damage inventory and analysis, system formulation and optimization models, environmental analysis and general data management and display tools (4).

In the early years (mid 1960's) data were assembled from maps, charts, and tables and then coded onto punched cards and loaded into computers through card readers. Results of analysis were generally printed output. Data transfer between programs was by use of punched cards (cards were punched on-line and used as input to the next program). Later (late 1960's), several smaller programs were consolidated into larger, comprehensive general purpose programs which in effect internalized data transfer between programs. Area and spatial data continued to be manually extracted from maps and transfered to program use via punched cards. In the early to middle 1970's, computer programs grew in conceptual scope and physical size and problems of transfer of data between programs began to once again emerge as important. Specially written files (normally tape/disk/drum) were generally used for transfers. Area and spatial data continued to be manually extracted from maps.

A major advance in data management responsive to water resources planning for the Corps occurred in the mid to late 1970's. The spatial data management system now known as HEC-SAM (5), was created to provide Corps planning with the capability to create, access, update, analyze and interface other analysis procedures with computerized spatial data. The spatial map type data issue was successfully systematically managed within the HEC-SAM system but program data transfers continued to take place conventionally - manually or by use of off line punched cards. Presently, program data transfers (between spatial files, utility programs, and analysis programs) are mostly accomplished by uniquely created intermediate files. These files are unique to the generating and using computer programs. A major effort is required to keep track of files and correctly manage through machine job control cards the myriad of resulting unique files. It became evident that a more systematic general purpose data file management scheme would greatly simplify the task of exchanging data between computer models. The Hydrologic Engineering Center Data Storage System (HEC-DSS) (6) has been created to fulfill this role. It is a file/record management system that can be called by generating and/or using programs to create and/or supply data in a standard labeled format. It is expected to make major contributions to the systematic management of data exchange between computer programs.

SPATIAL DATA MANAGEMENT SYSTEM

System Characteristics and Capabilities

The HEC-SAM system is a general purpose spatial data file focused procedure with applications in water resources planning and management. The system is comprised of a family of data management and analysis computer programs. Figures 1A and 1B present a functional flow diagram of the data management, analysis, and output of HEC-SAM. The solid lines indicate file transfers that are automated and the dashed lines file transfers that are presently under development. Eventually, file transfers between programs will be via the HEC-DSS mechanism described later.

The system has three distinct functional elements: Data File Management, Data File Processing Interface, and Comprehensive Analysis. The capped labels in the boxes are titles of individual computer programs. The computer programs comprising each of these functional

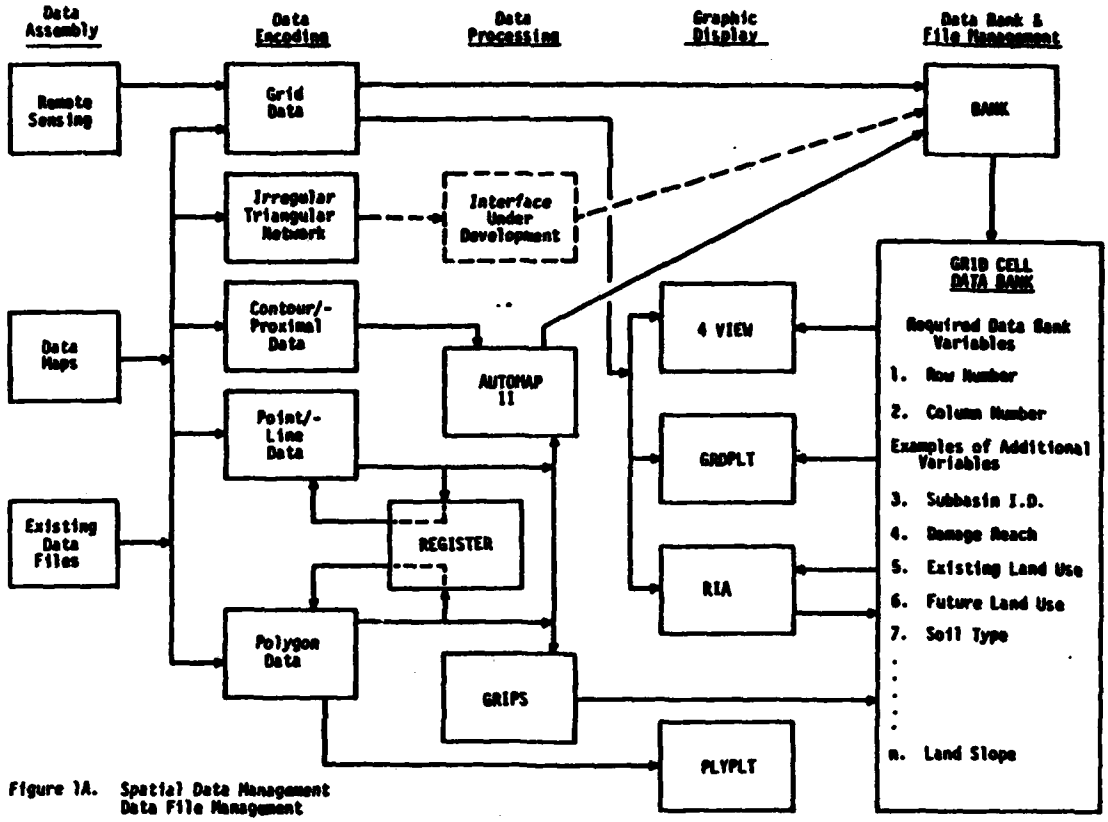

Figure 1A. Spatial Data Management
Data File Management

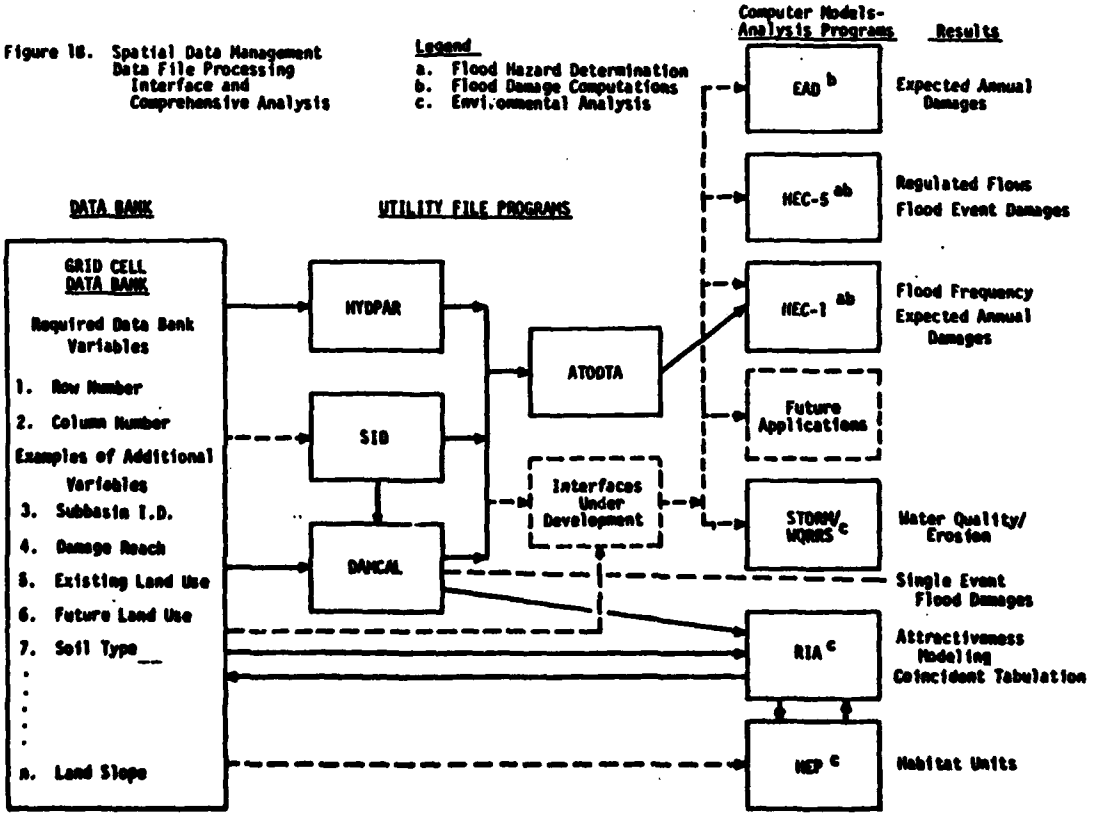

Figure 1B. Spatial Data Management
Data File Processing Interface and Comprehensive Analysis

elements are described in (5). The data file management element (Figure 1A) is comprised of the subfamily of computer programs required to process raw map or other type data to the grid cell format of the general data bank. The Data File Processing Interface element (utility file programs of Figure 1B) is comprised of computer programs that compile and reformat grid data retrieved from the data bank into a form processable by the general analysis computer programs.

The Comprehensive Analysis element (Computer Models - Analysis Programs of Figure 1B) is comprised of the generalized computer programs that perform detailed technical assessments using the linked input data files. These computer programs are standard tools used within the Corps that have been modified to accept data file input as an alternative to the usual card input and, in a few instances, modified to encourage increased systematic analysis to take advantage of access to a comprehensive data bank.

The system envisions that the basic spatial data that is normally used in map form during planning studies would be processed into a spatial data file by application of the various Data File Management programs. Analysis is performed for a selected condition, (e.g., a projected land use pattern with a certain flood hazard zoning policy or project) by processing the proposal into the data bank as a new (or modified) variable and successively executing the appropriate Interface and Comprehensive Analysis programs.

The analysis programs require specific input data that come both from the data bank and other sources. The initial model calibration is based on observed data supplemented by parameters generated from the data bank. The calibration data are used as the mechanism for forecasting the change in modeling parameters that would result from changed conditions or proposals. The output from these programs includes detailed numeric printout of the complete range of technical output of comprehensive flood plain assessments and grid map graphic displays of the data variables and results of attractiveness and impact analysis. Higher quality graphics can be generated from grid and polygon files if desired.

The general capability of HEC-SAM is to provide for assessment of alternative development patterns and flood mitigation plans in the functional areas of flood hazard, flood damage and environmental status. HEC-SAM can evaluate a specific storm event or develop flow and/or elevation exceedance frequency relationships for changed land use patterns and drainage systems, flood plain occupancy encroachments, and engineering works of levees, channel modification, reservoir storage and flow rerouting. HEC-SAM can evaluate the dollar damage for a specific event and the expected value of annual damage for changes in the following: flood plain occupancy, watershed runoff and stream conveyance, structural construction practices, development control policies, values and damage potential of flood plain structures, and effects of engineering works. HEC-SAM can perform a variety of environmental evaluations for the alternatives and conditions described above. The evaluations that can be performed are: forecast changes in wildlife habitat units, forecast changes in land surface erosion, forecast changes in runoff and

stream water quality, develop first order attractiveness and impact spatial displays.

HEC-SAM was initially developed to service a series of pilot studies, called Expanded Flood Plain Information Studies, which were designed to test the basic concepts of a broadened community service's oriented type of investigation which was under study by Corps management. These pilot studies are now completed. A group of Corps regular planning studies using HEC-SAM have been initiated this past year. Publications are available describing the research and documenting the initial pilot study findings (7, 8, 9) and documenting selected completed field applications (10, 11). To date, 35 studies have been initiated that involve substantial use of spatial data management techniques. Twenty have been completed, 15 are actively underway and an additional 10 are pending decisions for initiation.

HEC DATA STORAGE SYSTEM

The HEC Data Storage System (HEC-DSS) is a file management system designed to allow the orderly exchange of data between any HEC (and non HEC) computer programs. The HEC-DSS system routines are called by the generating or using program to create and/or supply data in a standard retrievable format. The common mode in which it is being implemented is to provide calling routines at the location within the computer code of a simulation model that data would be written out and/or read in. The files are random access with heirarchial pathname concepts implemented to control data flow (6).

HEC is committed to implementing the system for its general purpose computer programs and has set the goal for the near future of making the HEC-DSS system an integral part of HEC programs. It will be the mechanism for transfer of data between programs and in addition is expected to be a major adjunct to the systematic management of field collected and/or manually prepared data for use by HEC programs. General purpose tabulation, report generation, statistical analysis and computer graphics routines will be appended to the HEC-DSS. Eventually, special tabular, plot and other routines that were in the past written and implemented specifically for each HEC program will be discarded and the standard general appendages to the HEC-DSS used in their place through the HEC-DSS medium. Figure 2 portrays the expected mode of use of the system. The applications programs listed are a selected set of existing generalized HEC programs that include a rainfall-runoff model, reservoir system model, and flood damage analysis models. The utility programs that have thus far been defined (and shown on the figure) are in the developmental stage. The titles are indicative of the function they are expected to perform. The use and management of the large and growing family of HEC computer programs should be significantly enhanced by the HEC-DSS system.

EXAMPLE APPLICATION

Background

The data management concepts described herein are being implemented on a growing list of Corps investigations. They have been jointly implemented for a high priority planning investigation for the

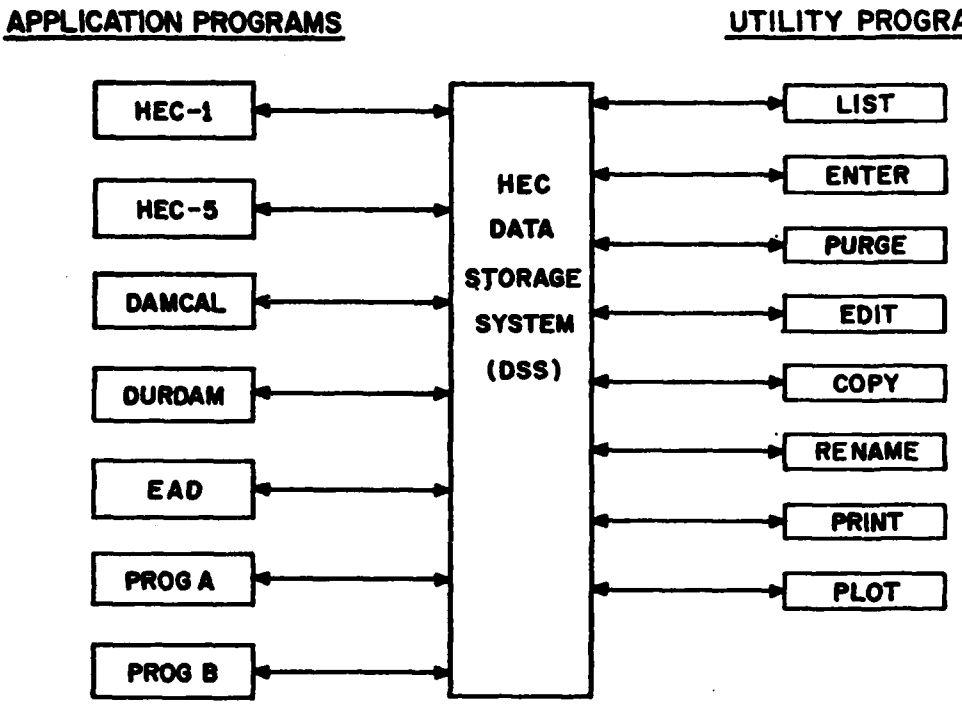

Figure 2. HEC-DSS Schematic

Kissimmee River Basin in south-central Florida. The study is examining a wide range of measures of physical works, land use management, and system operational modifications designed to provide major environmental enhancements in the project area (by such means as wetlands creation) while preserving the existing flood control performance of the recently completed major flood control project. The study area is large in geographic scope (3000 square miles), diverse in development characteristics (wetlands, forest area, improved pasture, orchards and urban), and complex in its hydrologic characteristics - the area is flat with many natural lakes and man-made control structures (12).

The decision was made that the analytical strategy for study performance would include the creation of a spatial data file in conjunction with linked analysis programs (13). The spatial data file includes such variables as land use, hydrologic/hydraulic reaches, damage areas, and environmental habitats, to enable study of the spatial and land use aspects of the study. The spatial files are linked to a family of computer programs (also linked to each other) that enable detailed analysis of alternatives. Figure 3 is a schematic of the processing flow for the hydrologic and flood damage analysis of the study. Other environmental analysis that make use of programs linked to the spatial (grid cell) data bank will be performed but are not shown.

Data Management and Computational Strategy

Rainfall-runoff analyses are performed to calculate runoff hydrographs at specified locations, land use management and time horizons of interest throughout the watershed (step 1 through 3). The watershed

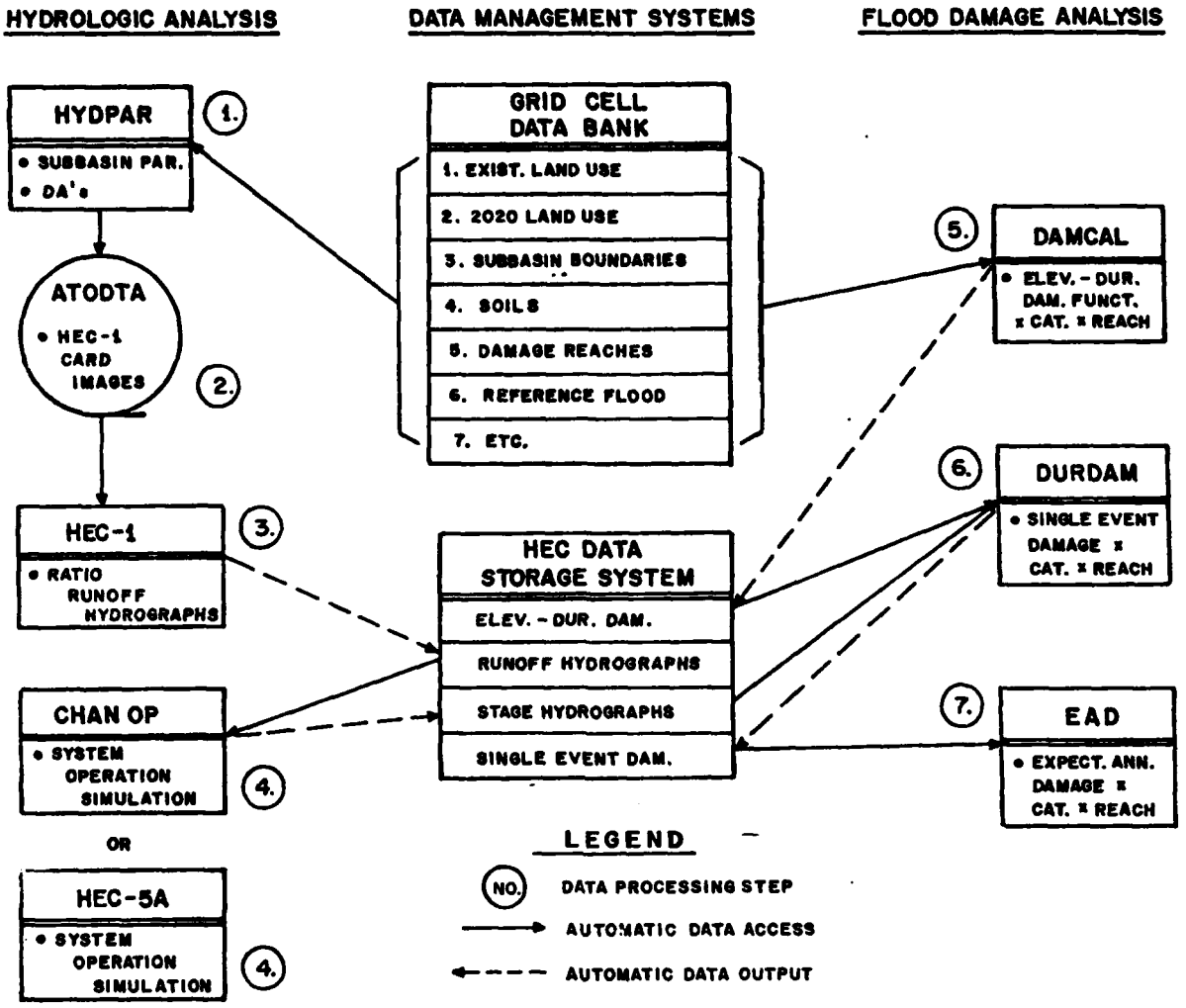

Figure 3. Data Processing Flow
Kissimmee Investigation

subdivision into subbasins are included as a variable in the grid cell bank. The HYPAR Program (step 1) automatically generates from appropriately specified data bank variables subbasin drainage area sizes, and hydrologic computation parameters. The HEC-DSS system has not yet been implemented for this step. The ATODTA Program (step 2) accesses these data files and processes the hydrologic parameter data into output files in HEC-1 card image format. The appropriate ATODTA output files are accessed by HEC-1 (step 3) and used to perform rainfall-runoff analyses of associated alternative projects and land use conditions. The HEC-1 rainfall-runoff results constitute a series of hydrographs at each of the designated locations from ratios of input hypothetical precipitation distribution. The runoff hydrographs are output to HEC-DSS for access as input into the analysis programs (CHANOP or HEC-5) for simulation of the operation of the flood control structures of the Kissimmee River watershed.

The CHANOP program (step 4) has been developed to simulate the unique operation of the flood control structures and lakes in the Kissimmee watershed. The CHANOP program automatically accesses the HEC-1 generated hydrographs from HEC-DSS, performs the simulation analysis and outputs to HEC-DSS, stage-hydrograph records for each ratioed event at each damage reach index location. As an option the HEC-5 Program (step 4) may be utilized.

The expected annual damage computation for alternative proposals is performed in three data processing and analysis phases (steps 5 through 7). The initial phase (step 5) generates elevation-area (duration) damage relationships using the DAMCAL Program from the spatial data file; the second phase (step 6) computes flood damage associated with flood hydrographs (duration considered) using the DURDAM Program; and the final phase (step 7) computes expected annual damage using the EAD program. The DAMCAL results are aggregated elevation-area-duration damage functions by category and are written to HEC-DSS for subsequent access by the DURDAM Program. The DURDAM Program (step 6) accesses the stage-hydrographs (either CHANOP or HEC-5 generated) and the corresponding elevation-duration damage relationships (DAMCAL generated) from the HEC-DSS and calculates single event damage associated with each ratioed hydrograph. These values are output to HEC-DSS for subsequent access by the EAD Program. The EAD Program (step 7) accesses the single event damage results generated by the DURDAM Program from HEC-DSS. These values, along with associated flood frequency assignments comprise the EAD Program input. The results computed are expected annual damage by category at each damage reach. The EAD program is executed each time an alternative is to be evaluated. This processing strategy is repeatedly performed, either beginning with, for example a new land use management condition (step 1 through 7) or with alternatives that can be studied using previously developed intermediate results, for example changed operational procedures (steps 4 through 7).

SUMMARY AND CONCLUSIONS

The HEC-SAM system evolved from a need within the Corps to manage spatial data in a systematic way to achieve an increased level of analysis capability for planning studies. The system includes capabilities to create and maintain spatial data files, retrieve and display file contents, and link data sets to sophisticated computer models. The HEC-DSS system emerged from the need to provide simple, efficeint data exchange between modern water resources planning analytical programs. The system is expected to contribute substantially to broadened integrated use of analysis programs by interdesciplinary professional study teams.

ACKNOWLEDGEMENTS

The original concept for the HEC-SAM system and supervision of its continuing development and servicing has been the responsibility of the author. Staff members at the HEC who contributed substantially include R. Pat Webb--responsible for most of the original development work, Shelle Barkin--continued development and day-to-day servicing, and Mike Burnham--source of many ideas in systems formulation. Jack Dangermond of ESRI has provided software and a continuing flow of ideas. Dr. Males of W. E. Gates and Associates has provided ideas as well as continuing moral support. The original concept of HEC-DSS system and

supervision of its continuing development is the responsibility of Dr. Arthur Pabst, Chief of HEC's Computer Support Group. Mr. Mark Lewis of the HEC staff performed the basic developmental work on the system. The HEC has been under the direction of Mr. Bill S. Eichert during the time these systems were under development.

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